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Evaluation of environmental impact of e-waste dumpsite on heavy metal composition of selected vegetables

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ABSTRACT

Electronic waste (e-waste) has emerged as a global environmental challenge because of its massive production volume, insufficient management policy in many countries and associated health risk. This study evaluated the environmental impact of e-waste dumpsite, considering the heavy metals assimilation through the soil to contaminate vegetables. Samples of 3 different types of edible vegetables (cucumber, water melon and garden egg leaves) were collected from a site located very close to the e-waste dumpsite in three locations (namely: Ochanja, Venn Road and Obosi town). The vegetables were analyzed to ascertain the heavy metal concentration on the raw vegetables in order to determine the bio-concentration or accumulation of the metals. Pb, Ba and Fe concentration was exceeded in water melon and garden leave only, Cr and Al exceeded the maximum limit in all the vegetables, while Ag, Cu and Cd were below the permissible limit. The concentration of most metals exceeded the maximum limit recommended by WHO and FAO (2010); this indicates excessive contamination and health risk associated with consuming vegetables from the e-dumpsites locations. It is suggested that suitable remediation measures should be adopted in the region.

Keywords: Heavy metal, Environmental monitoring, E-waste, Food security

1. INTRODUCTION

Because of the rapid growth of technology over the last few decades, the demand for electronic and electrical devices grows year after year. The lifespan of the device is shortened as newer models are produced and older ones are abandoned (Duman et al., 2019). Personal digital assistants (PDAs), personal computers, cathode ray tube televisions, cell phones, mice, keyboards, copiers and printers are some of the devices that are frequently manufactured as information technology advances. According to Kiddee et al., (2013), these items are disposed of as solid waste when they reach the end of their lifecycle. This is also known as WEEE (waste electrical and electronic equipment).

E-waste is one of the end-of-life (EOL) products with significant environmental impact. It is currently one of the fastest growing waste streams on

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the planet, with 20 to 50 million tons produced annually (Purchase et al., 2020). It is estimated that 70% of the heavy metals in municipal solid waste landfills come from electronic waste (Townsend, 2011). E-waste composed of 60% metals, 15% plastics and 5% metal-plastic mixture (Ari, 2016; Widmer et al., 2005). Eight metals (Pb, Cr, As, Zn, Cd, Cu, Hg and Ni) are the most widespread and harmful to the environment when their permissible levels are exceeded (Wang et al., 2007).

The uncontrolled processing of e-waste has resulted in the release of enormous amounts of metals into the local environment, resulting in high metal concentrations in the surrounding air, dust, soils, sediments and plants (Song and Li, 2015; Zeng et al., 2022). The popular methods of extracting valuable metals from e-waste, such as strong acid leaching and open burning of dismantled components, have resulted in the release of a large amount of harmful metals and organic contaminants into the environment (Gullett et al., 2007). According to Khaliq et al., (2014), metals are also liberated during the mining and extraction of various elements from their respective ores and return to the ground via dry and wet deposition.

Furthermore, the key factors that can influence metals release in the environment are rainfall type, intensity and pattern, temperature, wind and pH (Adesokan et al., 2016). Anthropogenic activities (such as mining and smelting operations, industrial production and usage, residential and agricultural use of metals and metal-containing compounds) cause metals to mix with the earth's crust, which results in serious human exposure. They gradually build up in terrestrial soil and plants. Metals cohabit and survive in soils as numerous contaminants, which makes it easier for these pollutants to enter food webs and build up until they eventually wind up in human diets.

Most e-wastes contain metals and other toxic substance; a study by Zeng et al., (2022) reported that heavy metals are found in e-wastes such as batteries and obsolete computers. The study also observed that these heavy metals cause kidney failure, brain damage etc. A recent study stated that exposure to e-waste can affect the various organs and tissues of the body, the study listed about seven (7) body systems that are affected by exposure to e-waste viz: urinary, skeletal, reproductive, respiratory, cardiovascular, immune and nervous systems (Brindhadevi et al., 2023). Another major concern on the impact of e-waste on human health is on genetic alteration and possibility of causing genetic changes (Zeng et al., 2022).

Hazardous e-waste in a study was associated to premature births, reduced birth weights, mutations, congential malformations, decrease in lung function, malfunction of the thyroid etc (Bruun and Lein, 2021). The health risk associated with the impact of formal or informal dumpsite of e-waste was recently investigated in South West of Nigeria, the study reported elevated level of heavy metal contamination of local soil in the study area (Adenuga et al., 2022). However, the study failed to investigate and analyze the composition of heavy metal on plants or vegetables. Consequent on the direct contact of humans with vegetables, it is critical to ascertain the degree of heavy metal contamination on edible plants.

Several studies have emphasized the need for proper and consistent environmental assessment on the impact of e-waste to human life. Studies have shown that plants can adsorb or uptake toxic metals from the soil through their roots translocate them to shoots and consequently store them in their tissues. Since most e-waste facilities are not restricted to agricultural environment, potential contamination is expected and further studies on the plants is essential (Brindhadevi et al., 2023). A study characterized the in vitro respiratory and oral bio-accessibility of As, Cd, Cr, Cu, Ni, Pb and Zn in soil–vegetable systems surrounding e-waste areas (Liu et al., 2022).

Crop production and crop quality are now significantly hampered by heavy metal contamination of the soil and water, which increases toxicity. Being sessile organisms, vegetable plants are unable to avoid unfavorable environmental changes. A greater variety of physiological and biochemical changes are brought on by heavy metal exposure. Heavy metals, both necessary and non-essential, typically have harmful effects on plants that include low biomass accumulation, chlorosis, suppression of growth and photosynthesis, altered water balance and nutrient assimilation and senescence. These effects eventually result in plant death.

Adenuga et al., (2022), investigated on the environmental impacts and health risks associated with three poorly managed e-waste dumpsites in Nigeria. A study in Brazil investigated the challenges and opportunities in e-waste management using reverse logistic (Santos and Ogunseitan, 2022). In a study in Vietnam, the researchers examined e-waste treatment options and the impact of e-waste heavy metal extraction on human health (Brindhadevi et al., 2023). Hybrid optimization of e-waste using deep learning platform in IoT cloud environment was applied as an option in managing e-waste (Ramya et al., 2023).

Despite various advanced approaches in mitigating the environmental impact of e-waste in various countries, many developing countries do not have adequate research in the assessment of environmental impact of e-waste. There is need to explore and direct studies on the environmental impact of e-waste, since there are scarce research works in this area; considering the importance of food security for economic and human development. This study is essential in sustainable environment for quality food production. The objective of this study is to evaluate the environmental impact of e-waste dumpsite on vegetables, considering the possibility of buildup of heavy metals in the environs.

2. MATERIALS AND METHODS

Description of the Study Area and E-waste Area

Anambra State is one of the 36 states of the federation and one of the five states in the South-East geo-political zone of the country. It is the gateway to Eastern Nigeria and economic nerve centre of Nigeria; the state is located in the transition area between the sub-equatorial climatic and the tropical hinterland climatic belts of Nigeria. The study areas include some selected towns in Anambra State of Nigeria, they are Ochanja market and Venn Road market both are located in the commercial city of Onitsha and e-waste dumpsite located in Obosi town. The three locations are known for deposition of e-wastes, the areas are generally within the industrial and commercial hubs of the study area. The three sites are showing the entire state geography (Figure 1). Onitsha is located on latitudes $5°22^1$ and $6^0 48^1$ and longitudes $6°32^1$ and $7°20^1$ in the Anambra North Senatorial Zone. It occupies the eastern bank of River Niger, covering some 50, 000 square kilometers and measures about 150 miles north of River Niger.

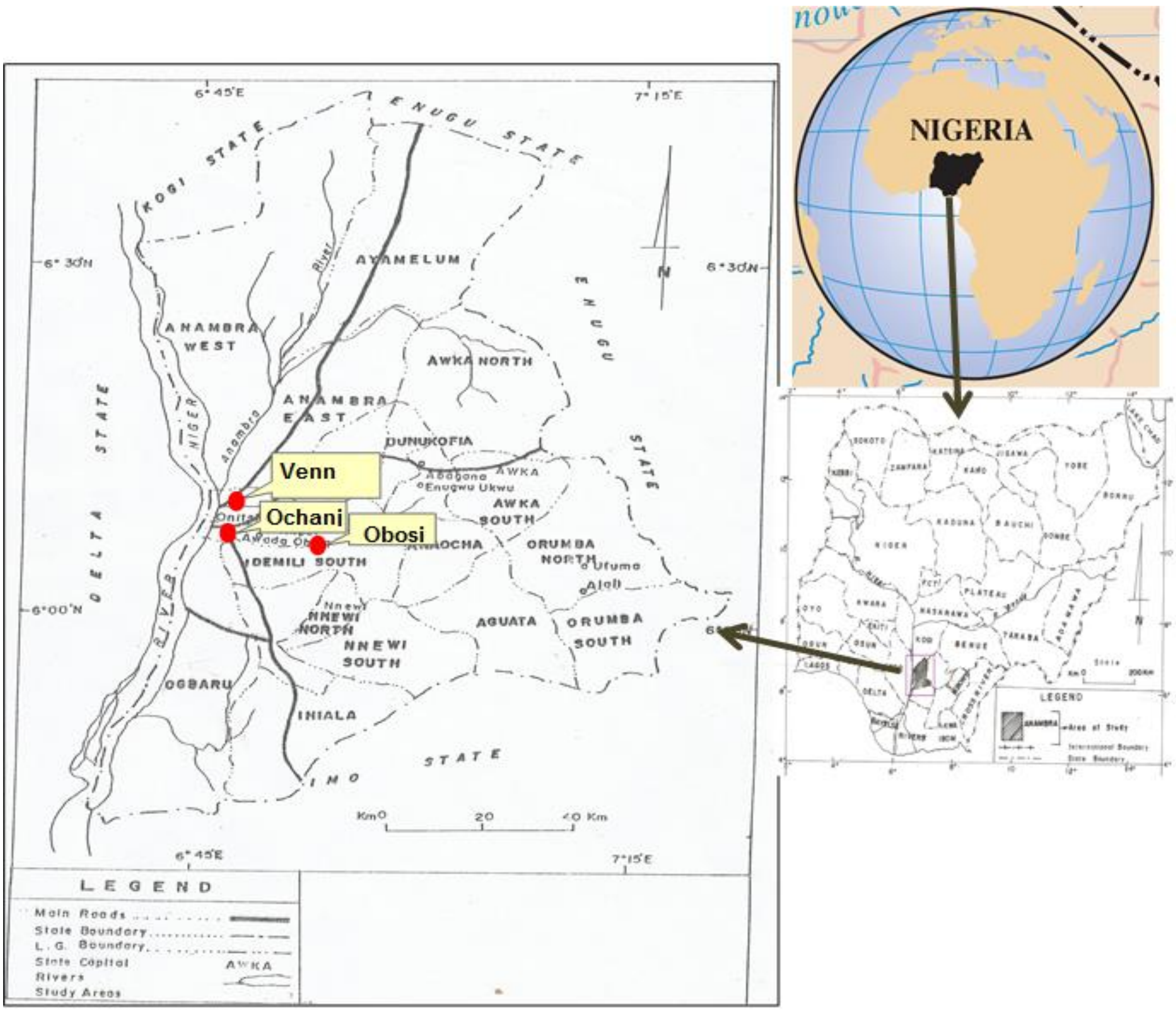

Figure 1 Map of the study area showing the E-waste dump site locations

Data Collection and Analysis

Twelve (12) samples of three (3) different types of edible vegetables (cucumber, water melon and garden egg leave) were collected from gardens located very close to the e-waste dumpsite. The three different types of vegetables assessed are water melon (citrulluslanatus), garden egg leave (s.macrocarpon) and cucumber (cucumissativus). The vegetables are common staple within the region and are consumed without cooking or further processing. The vegetables were analyzed to ascertain the heavy metal concentration on the raw vegetable in order to determine the bio-concentration of the metals on the vegetables, which is a pointer to its possible bioaccumulation in human.

Vegetable samples were washed in running tap water then with distilled water and carefully dried in oven at 70°C for 24hr. pre-weighed samples (200g for each) were ground in a pestle and mortar followed by wet digestion with HNO_3 and H_2O_2 (Tappi, 1999) in the ratio of 3:1. The samples were digested on a hot plate at a temperature of 93°C for 4 hrs. Heating was done such that it did not boil. Heating was done till it dried up completely and whitish brown dry mass was obtained. It was then cooled and the digest mixture was extracted in acid water mixture (HC1: Distilled water, ratio 3:1) and filtered through whatman filter paper. The filtrate was analyzed for the heavy metal content using AAS (GBC 932AA).

One-Way Analysis of Variance (ANOVA) was used to test for the physicochemical parameters of heavy metals on vegetables grown around the e- waste dump of the study area. The means, standard deviations and actual concentrations were calculated for the heavy metals in vegetables. Statistical significance of the difference of the mean values between different groups was determined by applying the F-test with the level of significance at $P>0.5$.

The correlation between the metals was observed using Pearson correlation analysis. The correlation coefficient 'r' is a measure of linear association between two variables. Values of the correlation coefficient are always between –1 and +1. A correlation coefficient of +1 indicates that two variables are perfectly related in positive linear sense; a correlation coefficient of –1 indicates that two variables are perfectly related in a negative linear sense and a correlation coefficient of 0 indicates that there is no linear relationship between the two variables.

3. RESULTS AND DISCUSSION

Heavy Metal Contamination of Vegetables

Three different types of vegetables, water melon (citrullus lanatus) and garden egg leave (s.macrocarpon) and cucumber (cucumis sativus) were analyzed for heavy metals content. Differences in metal concentration in vegetables seem to imply that different types of vegetables have different abilities to accumulate metals. Different types of vegetable species accumulate different metals depending on environmental conditions, metal species and plant available for heavy metals. The mean values of heavy metals in the vegetables from Obosi, Ochanja and Venn Road e-waste dumpsite is in (Table 1).

Table 1 Heavy metal concentration in vegetables at Obosi, Venn Road and Ochanja E-waste dump site (mg/kg)

S/N	Element	Type of vegetable	Obosi	Venn Road	Ochanja	FAO STD 2010
1	Pb	Water melon	0.87	0.62	0.65	0.30
		Garden egg leaves	0.74	0.89	0.75	
		Cucumber	0.27	0.05	0.05	
2	Cr	Water melon	1.36	0.18	0.17	0.10
		Garden egg leaves	0.36	0.14	0.16	
		Cucumber	0.15	0.12	1.11	
3	Ag	Water melon	0.16	1.27	1.28	50.00
		Garden egg leaves	0.24	2.08	2.09	
		Cucumber	0.36	2.05	2.05	
4	Cd	Water melon	0.17	0.15	0.16	500.00
		Garden egg leaves	0.14	0.13	0.14	
		Cucumber	0.12	0.10	0.11	
5	Ni	Water melon	0.33	2.06	2.06	67.00
		Garden egg leaves	0.20	2.04	2.05	
		Cucumber	0.16	2.02	2.01	
6	Al	Water melon	0.04	0.22	0.21	0.10
		Garden egg leaves	0.38	0.27	0.28	
		Cucumber	0.45	0.31	0.32	
7	Fe	Water melon	0.89	0.72	0.71	0.30
		Garden egg leaves	0.75	0.89	0.88	
		Cucumber	0.29	0.05	0.05	

8	Ba	Water melon	0.04	0.45	0.46	0.06
		Garden egg leaves	0.21	0.34	0.35	
		Cucumber	0.36	0.23	0.22	
9	Zn	Water melon	0.161	0.132	0.133	-
		Garden egg leaves	0.145	0.111	0.112	
		Cucumber	0.026	0.140	0.141	
10	Cu	Water melon	0.04	0.01	0.11	0.10
		Garden egg leaves	0.01	0.01	0.01	
		Cucumber	0.03	0.02	0.02	

From Table 1, the analyzed samples showed that the concentration of Pb in cucumber ranges from 0.05 mg/kg – 0.27 mg/kg. The concentration of Pb in water melon and garden egg were more than the maximum limit recommended by (FAO, 2010) in all the sampled. A similar study showed that Pb concentration ranged from 0.15 to 0.41 mg/kg dry weight samples which were closer to the data obtained in this study. The heavy metal concentration of chromium (Cr) was also ascertained as in the Table 1; the Table 1 further showed that the samples contain traces of Cr in the three e-waste dump sites with water melon ranging from 0.17 to 1.36, mg/kg of the dry samples.

The result showed that water melon concentration of Cr at Obosi is 1.36mg/kg, while, Venn Road is at 0.18mg/kg and Ochanja is at 0.17mg/kg. This showed that the concentration was lower at Venn Road and Ochanja, but the heavy metal concentration in the three locations or e-waste dump site contains metal (Cr) above the permissible limits of FAO standard (2010). Similarly, the concentration of cadmium in the samples was also evaluated. Table 1 showed that the concentration of cadmium to vary between 0.10 to 0.17 mg/kg, the permissible limits of 500.00 mg/kg was not exceeded in all the vegetables.

Table 1 also indicated that the concentration of Cd was higher in water melon compared to garden egg leave and cucumber. A previous study found that the Cd accumulation was more in leafy vegetables such as garden egg leaves, lettuce and spinach. In addition, the levels of Al, Ni, Ag, Ba, Fe, Zn and Cu investigated in the study showed that the accumulation of these metals in leafy vegetable could possibly lead to human health problems, since the concentration of these metals were slightly above the recommended limit by FAO (2010).

The elevated level of Pb in vegetables might be associated with its higher soil content of e-waste dumped in the study area. Long term exposure to Pb may result in impaired central nervous system, prolonged reaction times and reduced ability of understanding, while in children the exposure to Pb might result in behavioral disturbances as well as learning and concentration difficulties. The metal of which maximum concentration was recorded among all vegetables was Fe, which was in agreement with the results of 1998 study who also reported maximum accumulation of iron as compared to any other metal in vegetables.

Statistical Analysis of Heavy Metals Concentration

The correlation between the metals was observed using Pearson correlation analysis. The correlation coefficient 'r' is a measure of linear association between two variables. Table 2 shows the correlation result of the heavy metals from the dumpsites. From the test, positive correlation was observed between Pb and Cd (R=0.705, $P<0.01$), Pb and Cr (R=0.585), Pb and Cu (R=0.715), Pb and Fe (R=0.728), Pb and Ag (R=0.790), Pb and Al (R=0.601), Pb and Hg (R=0.685), Pb and Ba (R=0.710) and Pb and Ni (R=0.628).

Table 2 Pearson correlation analysis on the concentration between Heavy metals concentration of the vegetables

	Pb	Cd	Cr	Cu	Fe	Ag	Al	Hg	Ba	Ni
Pb Person correlation Sig (2-tailed)[b] N[c]	1	.705**	.585**	.715**	.728**	.790**	.601**	.685**	.710**	.628**
		.000	.000	.000	.000	.000	.000	.000	.000	.000
	10	10	.10	10	10	10	10	.10	10	10
Cd Pearson correlation Sig (2-tailed)[b] N[c]	.705**	1	617	570	-053	256	.570	617	570	-053
	.000		000	000	.455	000	.000	000	000	.455
	.10	10	10	10	10	10	. 10	10	10	10
Cr Pearson correlation Sign (2-tailed)[b] N[c]	.585**	.617**	1	631**	256**	.128**	.617**	.570	631**	256**
	.000	.000		000	000	.071	.000	.000	000	000
	10	10	10	10	10	10	10	.10	10	10

Cu Person correlation	.710**	.570	.63	1		631	.570	.63	.570	
Sig (2-tailed)[b] N[c]	.000	.000	000		.071	000	.000	000	.000	.071
	.10	.10	10	10	10	10	. 10	10	. 10	10
Fes Pearson correlation	.628**	.256**	470**	628**	1	470**	.256**	470**	628**	.570
Sig (2-tailed)[b] N[c]	000	.000	000	000		000	.000	000	000	.000
	. 10	.10	10	10	10	10	.10	10	10	.10
Ag Pearson correlation	.750**	.256**	470**	628**	470**	1	470**	470**	628**	470**
Sig (2-tailed)[b] N[c]	.000	.000	000	000	000		000	000	000	000
	. 10	.10	10	10	10	10	10	10	10	10
Al Pearson correlation	.710**	.570	.63	.710**	.628**	.750**	1	617	570	-053
Sig (2-tailed)[b] N[c]	.000	.000	000	.000	.000	.000		000	000	.455
	.10	. 10	10	10	10	10	10	10	10	10
Hg Pearson correlation	.628**	.256**	470**	570	-053	256	.617**	1	631**	256**
Sig (2-tailed)[b] N[c]	000	.000	000	000	.455	000	.000		000	000
	. 10	. 10	10	10	10	10	10	10	10	10
Ba Pearson correlation	.750**	.256**	470**	631**	256**	.128**	.570	.63	1	
Sig (2-tailed)[b] N[c]	.000	.000	000	000	000	.071	.000	000		.071
	.10	.10	10	10	10	10	.10	10	10	10
Ni Pearson correlation	.685**	.617**	.256**	470**	628**	470**	.256**	470**	628**	1
Sig (2-tailed)[b] N[c]	.000	.000	.000	000	000	000	.000	000	000	
	10	10	.10	10	10	10	.10	10	10	10

**: Correlation is significant at the 0.01 level (2-tailed).

The positive correlation of all the heavy metals suggests a common source of contamination of the vegetables. The result of the analysis from the heavy metal contamination of vegetables implies that consumption of these vegetables has the tendency of causing health challenges to the populace which could lead to malfunctioning of the organs of the body especially the liver and kidney. Therefore, people should be aware of the implications of farming close to e-waste dumpsite.

4. CONCLUSIONS AND IMPLICATIONS

The objective of this study is to evaluate the environmental impact of e-waste dumpsite on stable food (vegetables), over the tendency for buildup of heavy metals in plants. The three locations investigated in this study that are known for deposition of e-wastes in Anambra state are Ochanja market and Venn Road market both are located in the commercial city of Onitsha and e-waste dumpsite located in Obosi town. Three different types of edible vegetables (cucumber, water melon and garden egg leave) were collected from gardens located very close to the e-waste dumpsite.

Study indicated that the concentration of Pb in cucumber ranges from 0.05 - 0.27-mg/kg. The concentration of Pb in water melon and garden egg were more than the maximum limit recommended by FAO. The concentration of Cd was higher in water melon and lower in garden egg leave and cucumber. The concentration of Cd was relatively higher than the permissible limits in the three vegetables. Generally, a good number of heavy metal concentrations was higher than the recommended limit and indicates red flag and would constitute health risk to the consumers. The correlation analysis also indicated a common source of contamination of the vegetables within the area. It is recommended that adequate remediation method be employed to salvage the environment.

Informed consent

Not applicable.

Ethical approval

The ethical guidelines for plants & plant materials are followed in the study.

Conflicts of interests

The authors declare that there are no conflicts of interests.

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The study has not received any external funding.

Data and materials availability

All data associated with this study are present in the paper.

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